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## INTRODUCTION

This report represents the final report for the research carried out under the ARPA-ONR Contract Number N00014-75-C-0951-NR 049-328. During the course of this contract, there have been several major task areas:

1. The development of homomorphic signal processing techniques and their application to the development of a homomorphic vocoder and other signal processing applications.
2. The development and implementation of techniques for enhancement and bandwidth compression of degraded speech.
3. The development and evaluation of techniques for processing of multidimensional signals and the application of these techniques to image processing, and the processing of other multidimensional data sets.
4. The development of techniques and the implementation and evaluation of systems for speed transformations of speech.

In addition, in the course of this contract, there have been a number of other studies carried out relating to the development of signal processing techniques, as well as their implementation and application to particular problems of interest.

Throughout the course of this contract, we have reported the details of our various research efforts in the form of journal

articles and in some cases technical reports. At the end of this final report is a complete listing of the technical reports and journal articles reporting work carried out under the contract. A number of the papers supported under this contract and listed in the bibliography received major IEEE awards. In the following sections, we give a brief overview of the work carried out under the various categories indicated above.



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## HOMOMORPHIC SIGNAL PROCESSING

A major focus of the work under this contract has been the development of homomorphic signal processing techniques directed principally at the development of a low-cost homomorphic vocoder. As part of this work, a number of basic new algorithms were developed for homomorphic signal processing including the development of a new phase unwrapping algorithm and the development of techniques for homomorphic processing using both the conventional and sliding chirp z-transform. Also out of this study emerged a synthesis of the techniques of homomorphic filtering and linear prediction analysis. This new modified technique has been labeled as homomorphic prediction.

Much of the emphasis on the application of homomorphic techniques to speech compression has centered around the incorporation of phase. To accomplish this, a set of detailed techniques for phase estimation with particular application to speech analysis-synthesis was explored and a number of iterative techniques were developed to accomplish the phase estimation. The importance of phase in relation to speech processing, as well as the processing of other signals, was a central theme throughout this work. In addition to the development of a system for the incorporation of phase, a more general theory relating to the importance of phase in both speech and pictures was developed. This basic and fundamental work was reported in an invited IEEE paper published in May 1981.

Another modified homomorphic technique which was developed and explored in considerable detail is referred to as spectral root homomorphic deconvolution. In addition to the development of the theory, the spectral root homomorphic vocoder was implemented and evaluated.

In addition to its application to speech processing, work was carried out to explore and develop the application of homomorphic filtering in the context of seismic data processing.

#### SPEECH ENHANCEMENT AND BANDWIDTH COMPRESSION

A second major project during the course of this contract was the development, implementation and evaluation of techniques for enhancement and bandwidth compression of degraded speech. The principal accomplishments on this project were reported in detail in an invited review paper published in the IEEE Proceedings in December 1979. The system which was developed and implemented centered around the all-pole modeling of speech taking into account the noisy observations. In addition to the implemented system being better in performance than other previous systems, a considerable body of important and useful theory relating to the modeling of signals which have been degraded by noise was developed.

## MULTIDIMENSIONAL SIGNAL PROCESSING

Our work on multidimensional signal processing had a very strong component relating to the development of the theory for multidimensional filtering and spectral analysis. A number of new multidimensional filter design techniques were developed and are now widely used throughout the community. Much of our early work in this area was published in an invited paper in the IEEE Proceedings on two-dimensional digital filtering. Important results were also obtained under this project on multidimensional spectral analysis. A basic new algorithm for two-dimensional maximum entropy power spectrum estimation was developed which resolves many of the algorithm problems previously encountered in relation to multidimensional power spectrum analysis. A new class of algorithms was also developed for the numerical evaluation of the hankel transform which corresponds to the two-dimensional Fourier transform of a circularly symmetric function. This latter algorithm was motivated in part by a problem relating to the measurement of the plane wave reflection coefficient of the ocean bottom and is now generally considered to be one of the most efficient algorithms for the computation of the hankel transform.

The theory that has been developed under this project for multidimensional signal processing has been applied in a number of areas. One, as indicated above, is in problems relating to

ocean acoustics. Also, much of the work has been implemented in relation to problems of image enhancement and restoration including the restoration of speckle images.

#### SPEED TRANSFORMATIONS OF SPEECH

During this contract, we developed, implemented, and investigated in detail techniques for speed transformations of speech, in particular, techniques for speeding up and slowing down speech while retaining very high quality. In addition to a successful implementation which resulted in a system of considerably higher quality than had ever previously been achieved, a basic new theory resulted on the short time Fourier analysis of speech and the use of this theory in the implementation of the digital phase vocoder.

#### GENERAL SIGNAL PROCESSING

In part as an outgrowth of the projects described above a number of other important studies were carried out under this contract. A theory was developed for the analysis of linear digital networks which was published in an IEEE invited paper. Work on computer architectures for signal processing, also published as an IEEE Proceedings invited paper, was carried out. More recently work under this contract, motivated in large part by our previous work on the importance of incorporating phase

information in vocoders, was carried out on the importance of phase in signals. Out of this study has emerged a rich and potentially very significant theory on signal reconstruction from either phase or magnitude information in the time domain or frequency domain.



PUBLICATIONS 1975 - 1981  
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JOURNAL ARTICLES, REPORTS AND BOOKS

1975

1. D. Dudgeon, "Existence of Cepstra for Two-Dimensional Rational Polynomials," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-23, no. 2, pp. 242-243, April 1975.
2. R. Crochiere and A. Oppenheim, "Analysis of Linear Digital Networks," IEEE Proceedings Special Issue on Digital Signal Processing, invited, vol. 63, no. 4, pp. 581-595, April 1975.
3. R. Mersereau and D. Dudgeon, "Two-Dimensional Digital Filtering," IEEE Proceedings Special Issue on Digital Signal Processing, invited, vol. 63, no. 4, pp. 610-623, April 1975.
4. J. Allen, "Computer Architecture for Signal Processing," IEEE Proceedings Special Issue on Digital Signal Processing, invited, vol. 63, no. 4, pp. 624-633, April 1975.
5. D. Dudgeon, "Two-Dimensional Recursive Filter Design Using Differential Correction," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-23, no. 3, pp. 264-267, June 1975.
6. R. H. Frazier, S. Samsam, L. D. Braida and A. V. Oppenheim, "Enhancement of Speech by Adaptive Filtering," RLE Progress Report No. 116, pp. 177-181, July 15, 1975.
7. E. Singer and A. Oppenheim, "Amplitude Filtering Using a Time Variable Transformation," RLE Progress Report No. 116, pp. 181-188, July 15, 1975.

1976

8. A. V. Oppenheim, M. R. Portnoff, "Speed Transformations of Speech," RLE Progress Report No. 117, p. 75, January 1976.
9. A. Oppenheim and E. Singer, "Enhancement of Lowpass Filtered Speech," RLE Progress Report No. 117, pp. 75-76, January 1976.
10. A. P. Holt, W.F.G. Mecklenbrauker and A. V. Oppenheim, "Design and Implementation of Variable Cutoff Digital Filters," RLE Progress Report No. 117, p. 76, January 1976.
11. G. E. Kopec, A. V. Oppenheim, "Speech Analysis by Homomorphic Prediction," RLE Progress Report No. 117, pp. 76-77, January 1976.

12. A. V. Oppenheim, J. M. Tribolet, "Applications of Homomorphic Filtering to Seismic Data Processing," RLE Progress Report No. 117, p. 77, January 1976.
13. H. W. Schuessler, "A Stability Theorem for Discrete Systems," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-24, no. 1, pp. 87-89, February 1976.
14. A. V. Oppenheim, W. F. G. Mecklenbrauker and R. M. Mersereau, "Variable Cutoff Linear Phase Digital Filters," IEEE Trans. on Circuits and Systems, vol. CAS-23, no. 4, pp. 199-203, April 1976.
15. M. R. Portnoff, "Implementation of the Digital Phase Vocoder Using the Fast Fourier Transform," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-24, no. 3, pp. 243-248, June 1976.
16. R. M. Mersereau, W. F. G. Mecklenbrauker and T. F. Quatieri, Jr., "McClellan Transformations for Two-Dimensional Digital Filtering: I. Design," IEEE Trans. on Circuits and Systems, vol. CAS-23, no. 7, pp. 405-414, July 1976.
17. W. F. G. Mecklenbrauker and R. M. Mersereau, "McClellan Transformations for Two-Dimensional Digital Filtering: II. Implementation," IEEE Trans. on Circuits and Systems, vol. CAS-23, no. 7, pp. 414-422, July 1976.
18. A. V. Oppenheim, G. Kopec and J. Tribolet, "Signal Analysis by Homomorphic Prediction," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-24, no. 4, pp. 327-332, August 1976.
19. A. P. Holt, "A Variable Cutoff Filter Using Digital Frequency Warping," S.M. Thesis, M.I.T., Dept. of Elec. Eng. and Comp. Science, September 1976.

#### 1977

20. D. B. Harris, J. H. McClellan, "Reconstruction of Velocity Structures from Teleseismic First Arrival Times," RLE Progress Report No. 119, p. 98, January 1977.
21. J. M. Tribolet, A. V. Oppenheim, "Application of Homomorphic Filtering to Seismic Data Processing," RLE Progress Report No. 119, p. 99, January 1977.
22. J. S. Lim and A. V. Oppenheim, "Enhancement of Degraded Speech," RLE Progress Report No. 119, pp. 99-100, January 1977.

23. E. Singer and A. V. Oppenheim, "Enhancement of Lowpass Filtered Speech," RLE Progress Report No. 119, pp. 100-101, January 1977.

24. T. F. Quatieri and A. V. Oppenheim, "Speech Analysis-Synthesis Based on Homomorphic Filtering and CCD Technology," RLE Progress Report No. 119, p. 101, January 1977.

25. M. R. Portnoff and A. V. Oppenheim, "Speed Transformations of Speech Signals," RLE Progress Report No. 119, pp. 101-102, January 1977.

26. G. E. Kopec, A. V. Oppenheim and J. M. Tribolet, "Speech Analysis by Homomorphic Prediction," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-25, no. 1, pp. 40-49, February 1977.

27. J. M. Tribolet, "A New Phase Unwrapping Algorithm," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-25, no. 2, pp. 170-177, April 1977.

28. J. M. Tribolet, "Seismic Applications of Homomorphic Signal Processing," Sc.D. Thesis, M.I.T., Dept. of Elec. Eng. and Comp. Science, May 1977.

29. D. B. Harris and R. M. Mersereau, "A Comparison of Algorithms for Minimax Design of Two-Dimensional Linear Phase FIR Digital Filters," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-25, no. 6, pp. 492-500, December 1977.

#### 1978

30. J. M. Tribolet, "Applications of Short-Time Homomorphic Signal Analysis to Seismic Wavelet Estimation," Geoexploration, vol. 16, pp. 75-96, January 1978.

31. A. V. Oppenheim, G. V. Frisk and D. R. Martinez, "An Algorithm for the Numerical Evaluation of the Hankel Transform," IEEE Proceedings Letters, vol. 66, no. 2, pp. 264-265, February 1978.

32. J. S. Lim and A. V. Oppenheim, "All Pole Modeling of Degraded Speech," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-26, no. 3, pp. 197-210, June 1978.

33. J. M. Tribolet, "Applications of Short-Time Homomorphic Signal Analysis to Seismic Wavelet Estimation," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-26, no. 4, pp. 343-353, August 1978.

34. J. S. Lim, A. V. Oppenheim and L. D. Braida, "Evaluation of an Adaptive Comb Filtering Method for Enhancing Speech Degraded by White Noise Addition," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-26, no. 4, pp. 354-358, August 1978.

35. J. S. Lim, "Enhancement and Bandwidth Compression of Noisy Speech by Estimation of Speech and its Model Parameters," Sc.D. Thesis, M.I.T., Dept. of Elec. Eng. and Comp. Science, August 1978.

36. A. V. Oppenheim and J. M. Tribolet, "Application of Homomorphic Filtering to Seismic Data Processing," chapter in: Applied Time Series Analysis, ed. David F. Findley, New York: Academic Press, pp. 261-286, September 1978.

37. J. S. Lim, "Evaluation of Correlation Subtraction Method for Enhancing Speech Degraded by Additive White Noise," IEEE Trans. on Acoustics, Speech and Signal Processing Letters, vol. ASSP-26, no. 5, pp. 471-472, October 1978.

38. T. F. Quatieri, Jr., "Short-Time Spectral Analysis with the Conventional and Sliding CZT," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-26, no. 6, pp. 561-566, December 1978.

#### 1979

39. B. R. Musicus, "An Iterative Technique for Maximum Likelihood Estimation with Noisy Data," S.M. Thesis, M.I.T., Dept. of Elec. Eng. and Comp. Science, February 1979.

40. J. S. Lim, "Spectral Root Homomorphic Deconvolution System," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-27, no. 3, pp. 223-233, June 1979.

41. J. S. Lim and H. Nawab, "Restoration of Speckle Images," Lincoln Lab. Technical Note No. 1979-52, July 3, 1979.

42. T. F. Quatieri, "Minimum and Mixed Phase Speech Analysis-Synthesis by Adaptive Homomorphic Deconvolution," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-27, no. 4, pp. 328-335, August 1979.

43. T. F. Quatieri, Jr., "Phase Estimation with Application to Speech Analysis-Synthesis," Technical Report No. 491, Res. Lab. of Elec., November 1979.

44. J. S. Lim and A. V. Oppenheim, "Enhancement and Bandwidth Compression of Noisy Speech," IEEE Proceedings, (invited), vol.

67, no. 12, pp. 1586-1604, December 1979 (also Lincoln Lab. Technical Note 1979-51, June 20, 1979).

1980

45. A. V. Oppenheim, G. V. Frisk and D. R. Martinez, "A Technique for the Evaluation of Circularly Symmetric Two-Dimensional Fourier Transforms and its Application to the Measurement of Ocean Bottom Reflection Coefficients," section of a book entitled DIGITAL SIGNAL PROCESSING, eds. V. Cappellini and A.G. Constantinides, pp. 87-95, London: Academic Press, 1980.

46. W. P. Dove, "Event Compression Using Recursive Least Squares Signal Processing," Technical Report No. 492, Res. Lab. of Elec., July 1980.

47. A. V. Oppenheim, G. V. Frisk and D. R. Martinez, "Computation of the Hankel Transform Using Projections," Journal of the Acoustical Society of America, vol. 68, no. 2, pp. 523-529, August 1980.

48. G. V. Frisk, A. V. Oppenheim and D. R. Martinez, "A Technique for Measuring the Plane Wave Reflection Coefficient of the Ocean Bottom," Journal of the Acoustical Society of America, vol. 68, no. 2, pp. 602-612, August 1980.

1981

49. A. V. Oppenheim and J. S. Lim, "The Importance of Phase in Signals," IEEE Proceedings Special Issue on Digital Image Processing, invited, vol. 69, no. 5, pp. 529-541, May 1981.

50. J. S. Lim and H. Nawab, "Techniques for Speckle Noise Removal," Journal of Optical Engineering, vol. 20, no. 3, pp. 472-480, May/June 1981.

51. J. S. Lim and N. A. Malik, "A New Algorithm for Two-Dimensional Maximum Entropy Power Spectrum Estimation," IEEE Trans. on Acoustics, Speech and Signal Processing, vol. ASSP-29, no. 3, pp. 401-413, June 1981, (also Lincoln Lab. Technical Note 1980-37, Aug. 7, 1980).

PAPERS SUBMITTED FOR PUBLICATION

52. M. Hall, A. V. Oppenheim and A. S. Willsky, "Time-Varying Parametric Modeling of Speech," IEEE Trans. on Acoustics, Speech and Signal Processing, submitted October 1979, revised September 1980.

53. J. S. Lim and N. A. Malik, "Maximum Entropy Power Spectrum Estimation of Signals with Missing Correlation Points," IEEE Trans. on Acoustics, Speech and Signal Processing Letters, accepted June 1981.

54. T. F. Quatieri and A. V. Oppenheim, "Iterative Techniques for Minimum Phase Signal Reconstruction from Phase or Magnitude," IEEE Trans. on Acoustics, Speech and Signal Processing, accepted July 8, 1981, (also Lincoln Lab. Technical Note 1980-34, Aug. 1, 1980).

55. A. V. Oppenheim, "Signal Reconstruction from Fourier Transform Phase or Magnitude," Summary of Basic Results for NSF Workshop, Aug. 27-29, 1981, La Spezia, Italy; and Florence Conf. on Digital Signal Processing, Sept. 2-5, 1981, Florence Italy, (in collaboration with M.H. Hayes and J.S. Lim).

CONFERENCES

1975

1. H. W. Schuessler, "On the Design of General Combfilters," Proceedings 1975 IEEE Int. Symposium on Circuits and Systems, pp. 400-403, Newton, Mass., April 21-23, 1975.
2. R. Mersereau, D. B. Harris and H. S. Hersey, "An Efficient Algorithm for the Design of Equiripple Two-Dimensional FIR Digital Filters," Proceedings 1975 Int. Symposium on Circuits and Systems, (invited) pp. 443-446, Newton, Mass., April 21-23, 1975.
3. A. V. Oppenheim, G. E. Kopec and J. M. Tribolet, "Signal Analysis by Homomorphic Prediction," Proceedings of the Plenary Assembly of the Int. Union of Scientific Radio, (invited), pp. 171-172, Lima, Peru, Aug. 13, 1975.
4. A. V. Oppenheim, G. E. Kopec and J. M. Tribolet, "Homomorphic Prediction," EASCON '75 Record, (invited), pp. 182-A - 182-F, Washington, DC, Sept. 29-Oct. 1, 1975.
5. W.F.G. Mecklenbrauker and R. M. Mersereau, "Efficient Design and Implementation for Two-Dimensional FIR Digital Filters Designed Using Generalized McClellan Transformations," EASCON '75 Record, pp. 185-A - 185-F, Washington, DC, Sept. 29-Oct. 1, 1975.
6. E. Singer and A. V. Oppenheim, "Amplitude Filtering Using a Time Variable Transformation," Proceedings of the Thirteenth Annual Allerton Conf. on Circuit and System Theory, (invited), pp. 457-466, Univ. of Illinois at Urbana-Champaign, Oct. 1-3, 1975.
7. A. Oppenheim, G. Kopec and J. Tribolet, "Homomorphic Prediction," Proceedings of the Ninth Annual Asilomar Conf. on Circuits, Systems and Computers, (invited), pp. 11-15, Pacific Grove, Calif., Nov. 3-5, 1975.
8. R. M. Mersereau and W.F.G. Mecklenbrauker, "Different Structures for the Implementation of Two-Dimensional FIR Digital Filters Designed by Transformations," Proceedings of Ninth Annual Asilomar Conf. on Circuits, Systems and Computers, pp. 393-397, Pacific Grove, Calif., Nov. 3-5, 1975.
9. G.E. Kopec, A. V. Oppenheim and J. M. Tribolet, "Speech Analysis by Homomorphic Prediction," Program of the 90th Meeting of the Acoustical Society of America, vol. 58, supplement no. 1, p. S97, San Francisco, Calif., Nov. 3-7, 1975.

1976

10. R. H. Frazier, S. Samsam, L. D. Braida and A. V. Oppenheim, "Enhancement of Speech by Adaptive Filtering," Proceedings of the 1976 IEEE Int. Conf. on Acoustics, Speech and Signal Processing, pp. 251-253, Philadelphia, Penna., April 12-14, 1976.
11. A. V. Oppenheim, "Everything you Always Wanted to Know about Homomorphic Filtering--but were Afraid to Ask," abstract, Lecture at Texas Instruments, Inc., Dallas, Texas, May 13, 1976.
12. A. V. Oppenheim and J. M. Tribolet, "Application of Homomorphic Filtering to Seismic Data Processing," informal summary of some basic concepts and notation for the Applied Time Series Symposium, pp. 5-18, University of Tulsa, Tulsa, Oklahoma, May 14-15, 1976.
13. D. S. K. Chan, "A Novel Framework for the Description of Realization Structures for 1-D and 2-D Digital Filters," Proceedings of the Electronics and Aerospace Systems Conference (EASCON), pp. 157A-157H, Arlington, Virginia, September 26-29, 1976.
14. J. H. McClellan and D. S. K. Chan, "A New Structure for 2-D FIR Filters Designed by Transformations," Proceedings of the Tenth Annual Asilomar Conf. on Circuits, Systems, and Computers, pp. 143-147, Pacific Grove, California, November 22-24, 1976.

1977

15. Y. M. Perlmutter, L. D. Braida, R. H. Frazier and A. V. Oppenheim, "Evaluation of a Speech Enhancement System," Proceedings of the 1977 IEEE Int. Conf. on Acoustics, Speech and Signal Processing, pp. 212-215, Hartford, Connecticut, May 9-11, 1977.
16. D. B. Harris and R. M. Mersereau, "A Comparison of Iterative Methods for Optimal Two-Dimensional Filter Design," Proceedings of the 1977 IEEE Int. Conf. on Acoustics, Speech and Signal Processing, pp. 527-530, Hartford, Connecticut, May 9-11, 1977.
17. D. B. Harris, J. H. McClellan, D. S. K. Chan and H. W. Schuessler, "Vector Radix Fast Fourier Transform," Proceedings of the 1977 IEEE Int. Conf. on Acoustics, Speech and Signal Processing, pp. 548-551, Hartford, Connecticut, May 9-11, 1977.
18. J. M. Tribolet, T. F. Quatieri, Jr. and A. V. Oppenheim, "Short-Time Homomorphic Analysis," Proceedings of the 1977 IEEE



Int. Conf. on Acoustics, Speech and Signal Processing, pp. 716-722, Hartford, Connecticut, May 9-11, 1977.

19. J. M. Tribolet and A. V. Oppenheim, "Deconvolution of Seismic Data Using Homomorphic Filtering," Proceedings of the Joint Automatic Control Conf., (invited), pp. 68-74, San Francisco, California, June 22-24, 1977.

20. M. Hall, A. V. Oppenheim and A. S. Willsky, "Time-Varying Parametric Modelling of Speech," Proceedings of the 1977 Decision and Control Conf., pp. 1085-1091, New Orleans, Louisiana, December 7-9, 1977.

21. G. V. Frisk, A. V. Oppenheim, D. R. Martinez, "A Technique for Measuring the Plane Wave Reflection Coefficient of the Ocean Bottom," abstract published in Journal of the Acoustical Society of America, Program of 94th Meeting, vol. 62, Supplement No. 1, p. S66, Miami, Florida, December 12-16, 1977.

#### 1978

22. T. F. Quatieri, Jr., "CCD CZT Spectral Analysis Applied to Real Time Homomorphic Speech Analysis-Synthesis," Proceedings of the 1978 IEEE Int. Conf. on Acoustics, Speech and Signal Processing, pp. 445-449, Camelot Inn, Tulsa, Oklahoma, April 10-12, 1978.

23. J. S. Lim, "Estimation of LPC Coefficients from Speech Waveforms Degraded by Additive Random Noise," Proceedings of the 1978 IEEE Int. Conf. on Acoustics, Speech and Signal Processing, pp. 599-601, Camelot Inn, Tulsa, Oklahoma, April 10-12, 1978.

24. A. V. Oppenheim, G. V. Frisk and D. R. Martinez, "A Technique for the Evaluation of Circularly Symmetric Two-Dimensional Fourier Transforms and its Application to the Measurement of Ocean Bottom Reflection Coefficients," (invited), Proceedings of the Int. Conf. on Digital Signal Processing, pp. 1-16, Facolta di Ingegneria, Universita di Firenze, Florence, Italy, August 30-September 2, 1978.

#### 1979

25. T. F. Quatieri, Jr., "A Mixed Phase Homomorphic Vocoder," Proceedings of the 1979 IEEE Int. Conf. on Acoustics, Speech and Signal Processing, pp. 56-59, Washington, DC, April 2-4, 1979.

26. B. R. Musicus and J. S. Lim, "Maximum Likelihood Parameter Estimation of Noisy Data," Proceedings of the 1979 IEEE Int.

Conf. on Acoustics, Speech and Signal Processing, pp. 224-227, Washington, DC, April 2-4, 1979.

27. J. S. Lim, "Spectral Root Homomorphic Deconvolution System," Proceedings of the 1979 IEEE Int. Conf. on Acoustics, Speech and Signal Processing, pp. 409-414, Washington, DC, April 2-4, 1979.

#### 1980

28. A. V. Oppenheim, M. H. Hayes and J. S. Lim, "Iterative Procedures for Signal Reconstruction from Phase," Proceedings of the 1980 Int. Optical Computing Conf., vol. 231, pp. 121-129, (sponsored by the Society of Photo-Optical Instrumentation Engineers), Washington, DC, April 7-11, 1980.

29. J. H. McClellan, "Artifacts in Alpha-Rooting of Images," Proceedings of the 1980 Int. Conf. on Acoustics, Speech and Signal Processing, vol. 2, pp. 449-452, Denver, Colorado, April 9-11, 1980.

30. W. P. Dove and A. V. Oppenheim, "Event Location Using Recursive Least Squares Signal Processing," Proceedings of the 1980 IEEE Int. Conf. on Acoustics, Speech and Signal Processing, vol. 3, pp. 848-850, Denver, Colorado, April 9-11, 1980.

31. J. S. Lim and H. Nawab, "Techniques for Speckle Noise Removal," Proceedings of the 1980 Int. Optical Computing Conf., vol. 243, pp. 35-44, (sponsored by the Society of Photo-Optical Instrumentation Engineers), San Diego, Calif., August 1980.

32. A. V. Oppenheim, "An Overview of Classical and High Resolution Spectral Estimation," Summary of Invited talk presented at the L'Aquila Workshop on Digital Signal Processing, L'Aquila, Italy, September 9-11, 1980.

33. A. V. Oppenheim and J. S. Lim, "Importance of Phase in Signals," poster session presented at the L'Aquila Workshop on Digital Signal Processing, L'Aquila, Italy, September 9-11, 1980.

#### 1981

34. S. W. Lang, G. L. Duckworth and J. H. McClellan, "Array Design for MEM and MLM Array Processing," Proceedings of the 1981 IEEE Int. Conference on Acoustics, Speech and Signal Processing, vol. 1, pp. 145-148, Atlanta, Georgia, March 30, 31, April 1, 1981.

35. J. S. Lim and N. A. Malik, "A New Algorithm for One-Dimensional and Two-Dimensional Maximum Entropy Power Spectrum Estimation," Proceedings of the 1981 IEEE Int. Conference on Acoustics, Speech and Signal Processing, vol. 3, pp. 1000-1005, Atlanta, Georgia, March 30, 31, April 1, 1981.
36. H. Nawab, A. V. Oppenheim and J. S. Lim, "Improved Spectral Subtraction for Signal Restoration," Proceedings of the 1981 IEEE Int. Conference on Acoustics, Speech and Signal Processing, vol. 3, 1105-1108, Atlanta, Georgia, March 30, 31, April 1, 1981.

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